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K-1656

AEC RESEARCH AND DEVELOPMENT REPORT

A DETECTOR FOR ALPHA RADIOACTIVITY IN FLOWING WATER

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UNION CARBIDE

UNION CARBIDE CORPORATION
NUCLEAR DIVISION

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A DETECTOR FOR ALPHA RADIOACTIVITY IN FLOWING WATER

by

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Report Date: April 19, 1966 Report Classification: Unclassified

A detector has been developed for monitoring continuously the alpha radioactivity in flowing water. The instrument is capable of detecting alpha levels down to 1 per cent of the maximum permissible concentration allowed for human consumption. The required maintenance is minimal, and it is suitable for location in a remote area. The design and test results are described.

This report consists of 19 pages, including 4 references and 8 figures. The work was completed in January, 1966.

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A DETECTOR FOR ALPHA RADIOACTIVITY IN FLOWING WATER

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A B S T R A C T

A detector has been developed for monitoring continuously the alpha radioactivity in flowing water. The instrument is capable of detecting alpha levels down to 1 per cent of the maximum permissible concentration allowed for human consumption. The required maintenance is minimal, and it is suitable for location in a remote area. The design and test results are described.

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A DETECTOR FOR ALPHA RADIOACTIVITY IN FLOWING WATER

INTRODUCTION

All flowing surface water, such as that present in creeks and rivers, contains radioactive materials. In the majority of cases the materials are present naturally from the dissolution of rocks and clays which originally contained minute traces of the radioactive elements. More recently the activity of some streams has been increased by the addition of fallout products and the addition by some chemical processing plants of waste products which contain radioactive materials.

Natural radioactivity is mostly negligible and practically undetectable. Fallout products are at a low level; and, in any case, the amounts presently in the atmosphere cannot be reduced artificially. The disposal of chemical waste containing radioactive materials is strictly controlled to insure adequate dilution. These factors make the radioactivity in flowing surface water well below the maximum permissible levels established by the U. S. Public Health Department.

In spite of the history of satisfactory performance in this area, it is the policy of the operators of plants processing radioactive chemicals to provide continuous or periodic inspection of streams in their areas to determine radioactivity levels.

The Oak Ridge Gaseous Diffusion Plant has had a program for such stream surveillance for many years. Instruments exist for the continuous monitoring for beta and gamma radiation. The alpha level is determined by obtaining a periodic grab sample, evaporating it to dryness, and counting the residue.

This paper describes an instrument for the continuous monitoring of a stream for alpha activity. It is expected that its use will further enhance the present program for the safeguarding of persons and property in the downstream area.

DESCRIPTION

The initial design used for the instrument was suggested by Petrock (2, 4). It consisted of a primary element for detecting the alpha particles and a counting and recording system for monitoring the output of the primary element. The system contained dual phototubes for increased sensitivity.

This primary element is shown assembled in figure 1 and partially cutaway in figure 2. The water chamber was in the shape of a disc 0.75 inches thick and 8 inches in diameter. The walls of the chamber were waterproof phosphor coated Mylar* supported by methacrylate light pipes. The edge

* Type APT-3, manufactured by William B. Johnson and Associates, Mt. Lakes, N. J.

of the chamber and all other metal parts in contact with the water were of nickel or nickel plated aluminum. A metal baffle in the center of the chamber prevented the scintillations from one side of the chamber from being detected by the phototube on the opposite side. The Mylar screen and the phototubes were optically coupled to the light pipes by silicone grease.* However, recent tests indicate that this grease is unnecessary. O-ring seals kept the water confined to the chamber. The coiled tubing at the inlet and outlet acted as light traps, keeping ambient light from reaching the phototubes. Water entered the primary element at the bottom and discharged at the top. The chamber volume was approximately 600 ml. The normal flow was about 60 ml. per minute, so that chamber filling required 10 minutes.

Scintillations resulting from alpha particles in the water were focused on the 5-inch multiplier phototubes. Their outputs were amplified and counted by conventional commercial electronic equipment. A high voltage attenuator was used to balance the phototube sensitivities. For long duration tests, the counts were recorded by a tape printer. This equipment arrangement is indicated graphically in figure 3.

After testing this primary element for several weeks, it was decided to change from a dual to a single phototube system. This decision was brought about by the difficulty experienced in (1) obtaining equal sensitivities for the two sides of the detector and (2) disassembly and reassembly of the chamber. It was apparent from the tests that the sensitivity of the system would be adequate with one tube only. At this time it was also decided to install a Streeter-Amet printer.

The revised primary element together with the electronic panels are shown in figure 4. The construction of the detector is basically the same as the prototype except that the phosphor disc, light pipe, phototube, and housing have been removed from one side and a blank flange added. The baffle plate has been retained to avoid fabrication of a new part; however, it is unnecessary.

The Streeter-Amet printer is also in place. The printer unit contains a predetermining counter and alarm system which can be set to provide a visible and an audible alarm in the event that the count rate rises above a preset value for the selected counting interval.

Figure 5 shows the major components disassembled except for the Mylar disc which is affixed to the larger face of the light pipe.

PERFORMANCE

The efficiency of the detection system is illustrated in figure 6. The average efficiency was 81.5 per cent. The range of efficiency about the median for the four source locations was ±11 per cent.

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* Type C-20057, Dow Corning Corp., Midland, Michigan

Initial tests using the dual primary element utilized distilled water for background measurements and acidic uranium solutions for attempted calibration. These tests indicated that the phosphor scintillator has an inherent "memory" or radioactivity retention which is not removed by water flushing. Attempts to remove it by mild acid cleaning destroyed the phosphor coating. Whether this characteristic is caused by a chemical or mechanical deposition on the phosphor is unknown. Since the water present in streams normally causes no detectable retention, this problem does not appear to be serious.

A subsequent calibration attempt utilized a uranium solution which had been neutralized with ammonium hydroxide and complexed with ammonium oxylate. This solution also exhibited "memory" but to a lesser extent.

This buildup of radioactive material on the phosphor, together with the resulting decrease in solution activity, made a true calibration impossible. An attempt to correlate initial solution activity with initial count rate failed, even when the solution was passed through the chamber several times.

The only check which could be made was a sensitivity check in which distilled water followed by a known contaminated solution was passed through the chamber. The increase in the count rate in the presence of the contamination is an indication of the ability of the instrument to detect alpha radioactivity in water. Figures 7a and 7b are graphs of such tests. Figure 7a was obtained with the dual chamber and 7b with the single detector. The failure of the data in 7b to show any decrease after the reintroduction of distilled water can possibly be explained by a slight difference in the contaminated solution used. For this experiment the solution was neutralized at twice the radioactivity level and then diluted to strength with water. Thus this solution was deficient in the complexing compound and would therefore plate out more readily in the chamber.

As is evident from these alpha sensitivity tests, the instrument is easily capable of detecting one picocurie per milliliter, which is 5 per cent of the maximum permissible count (MPC) for alphas in water for human consumption (1). In fact, it appears that 1 per cent of the MPC would be detectable under ideal conditions.

For the majority of tests, data from the counter have been accumulated over one hour intervals. For a few they have been taken every ten minutes. The former period appears to be more satisfactory because of the high statistical fluctuation present with ten-minute counts.

Figures 8a and 8b are graphs of the count rate obtained from monitoring water from the Clinch River. The instrument was located in the water filtration building K-1515. The data for figure 8a were obtained by passing sanitary water through the dual chamber. Figure 8b was obtained by passing raw water through the single ended chamber. The raw water was passed through a cotton mesh filter to remove the silt, but otherwise was untreated.

Sanitary water has been passed through the instrument for as long as two weeks with no apparent effect on the cleanliness or sensitivity of the primary element. Raw water from the Clinch River plugged the needle valve and flowmeter associated with the chamber in two days. A filter element from an automobile oil filter eliminated the plugging; however, its life was too short to be of value for extended use. The unit scheduled for long term service now being assembled will utilize a commercial ceramic water filter together with a flow controller.

As long as the water being monitored is free of artificially induced radioactive materials, the phosphor is essentially unaffected. Should a detectable amount of radioactivity be encountered, it may be necessary to replace the phosphor sheet which is a comparatively simple task.

CONCLUSION

The performance of the detector for alpha activity in flowing water can be properly evaluated only during long-term service monitoring raw river water. It can easily be operated in a remote area, such as beside a river or creek, by adding a pump for water circulation and a cubicle for protection from the weather. Electric power would, of course, be required. The maintenance of this instrument should consist almost wholly of changing the phosphor disc and water filter element periodically, which promises to be infrequently. To facilitate disc replacement, the present multiple bolt design can be eliminated in favor of a clamp arrangement.

This alpha detector should prove to be a valuable addition to the large number of instruments presently in use to safeguard and protect the ORGD plant equipment and personnel.

ACKNOWLEDGEMENT

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PHOTO NO. PH-65-1132

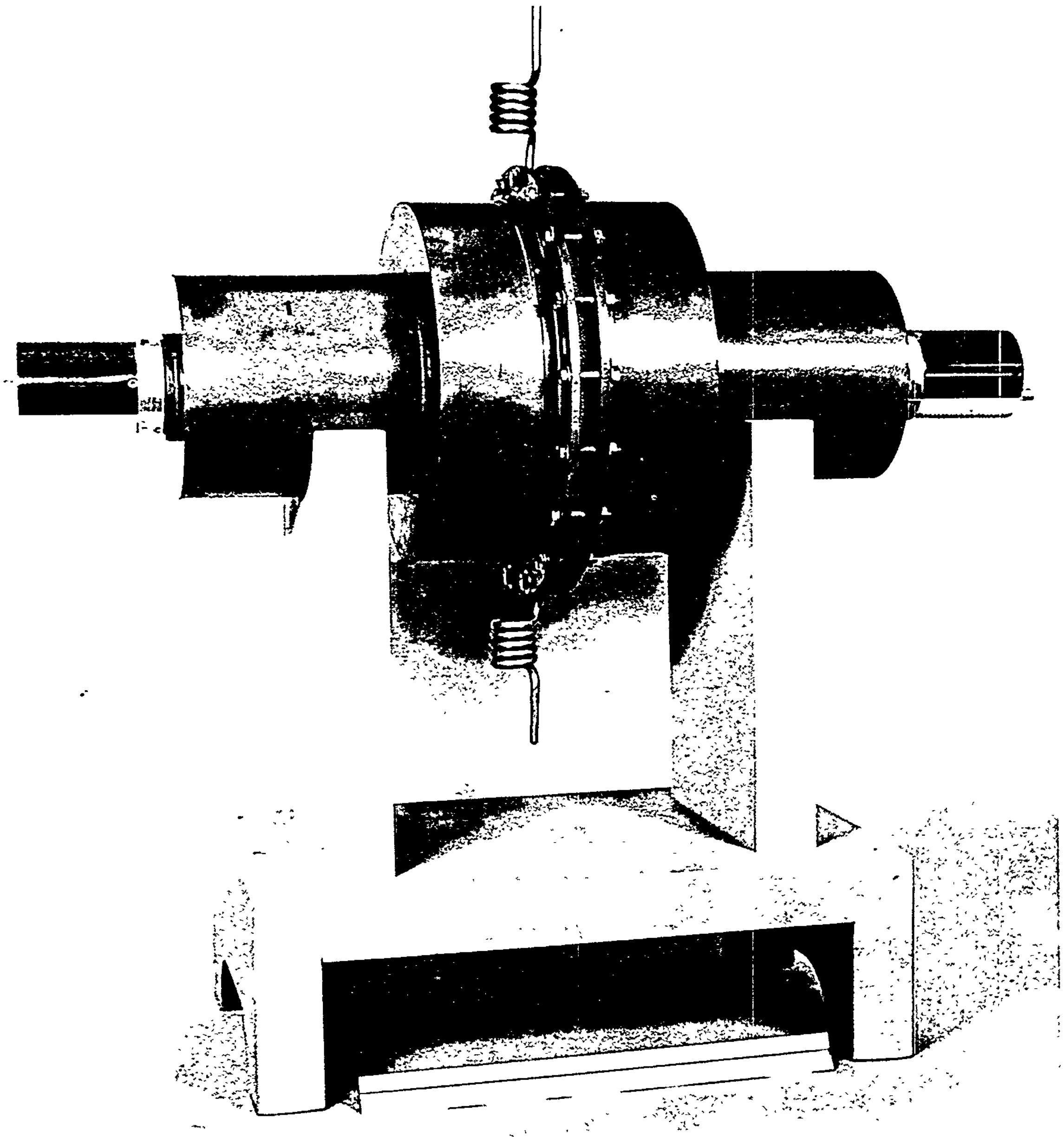


Figure 1

DUAL PRIMARY ELEMENT UNIT

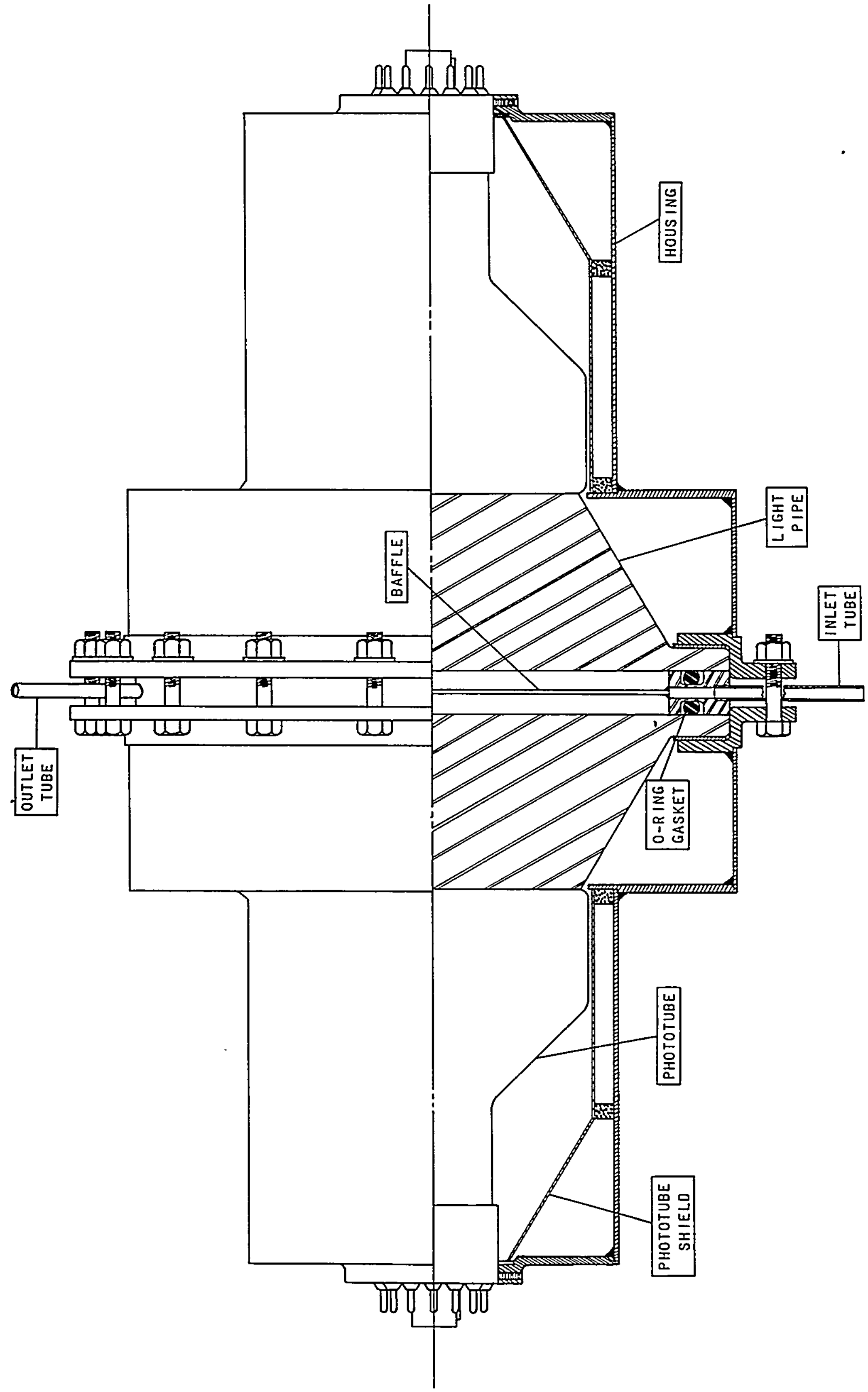
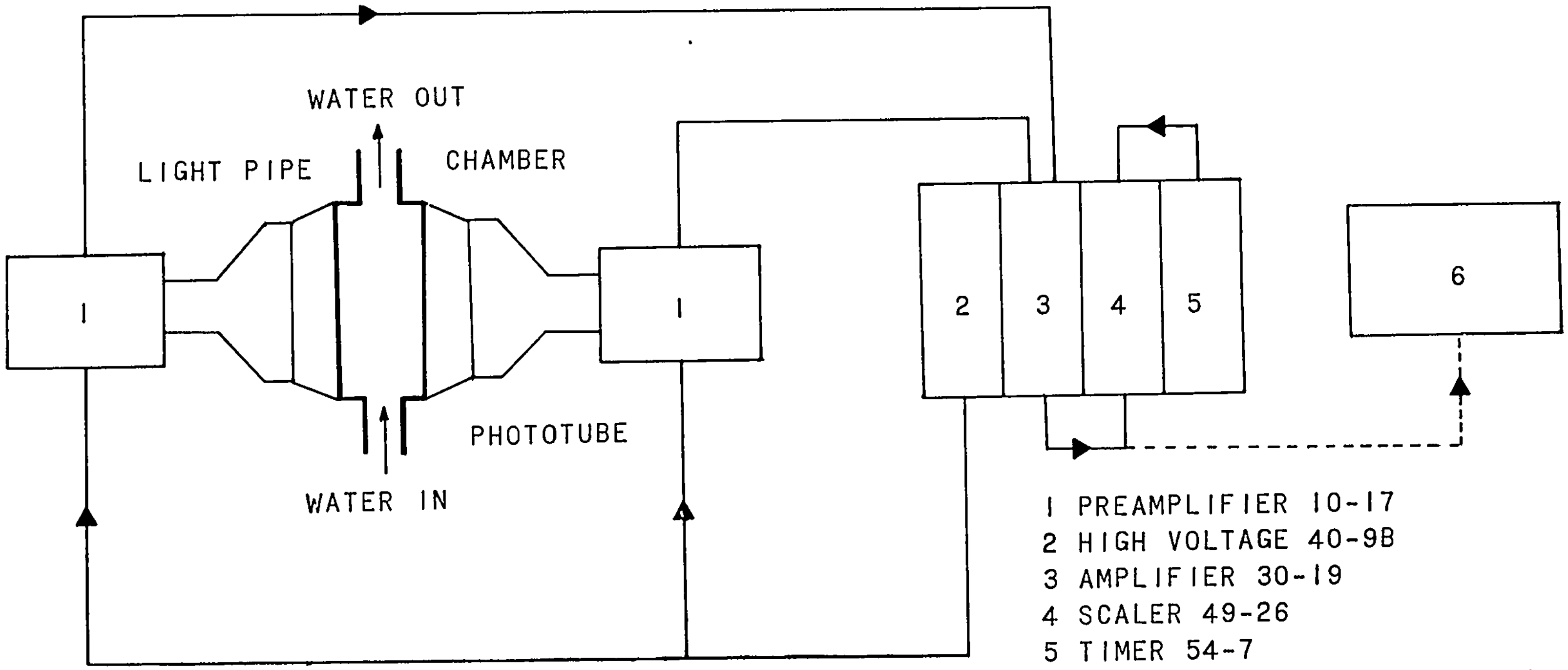


Figure 2
ASSEMBLY OF DUAL PRIMARY ELEMENT UNIT



1 PREAMPLIFIER 10-17
2 HIGH VOLTAGE 40-9B
3 AMPLIFIER 30-19
4 SCALER 49-26
5 TIMER 54-7
6 PRINTER - TEXAS INSTR. CPA-44

NOTE: ITEMS 1-5 ARE RADIATION INSTR. DEV. LAB. "DESIGNER" SERIES

Figure 3

EQUIPMENT DIAGRAM USING DUAL PRIMARY ELEMENT UNIT

PHOTO NO. PH-66-117

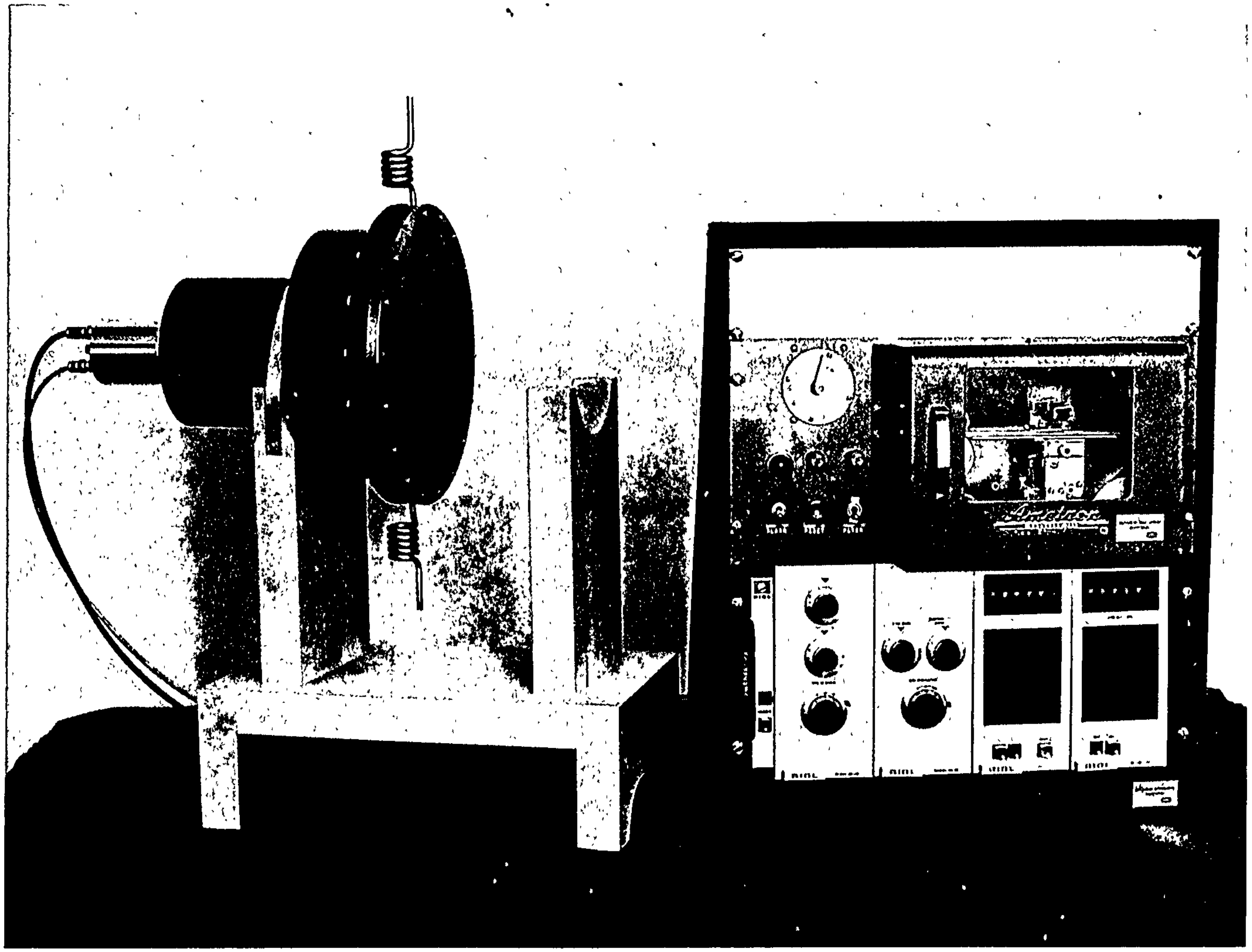


Figure 4

COMPLETE INSTRUMENT USING SINGLE PRIMARY ELEMENT UNIT

PHOTO NO. PH-66-116

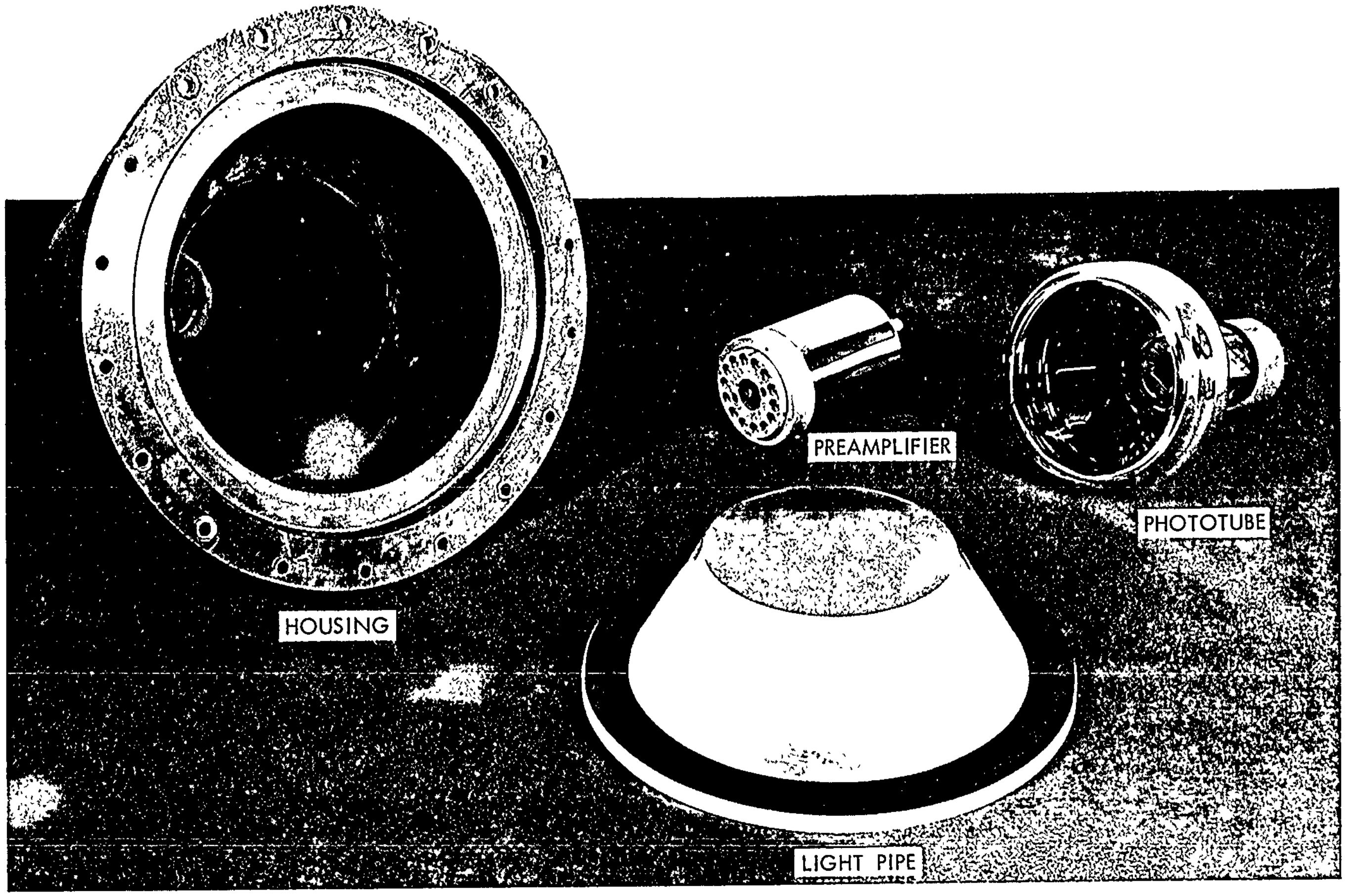


Figure 5

MAJOR DETECTOR COMPONENTS

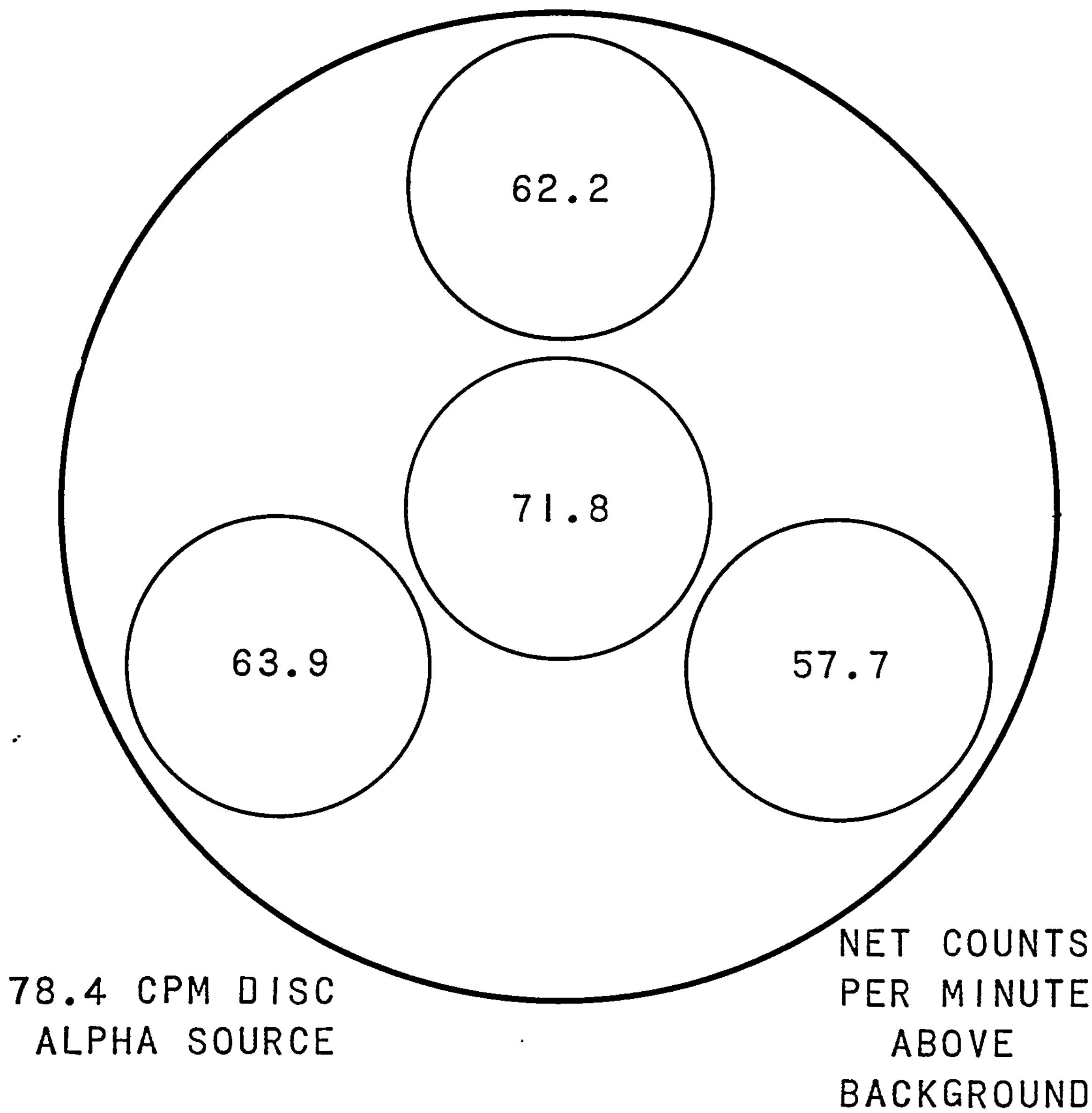
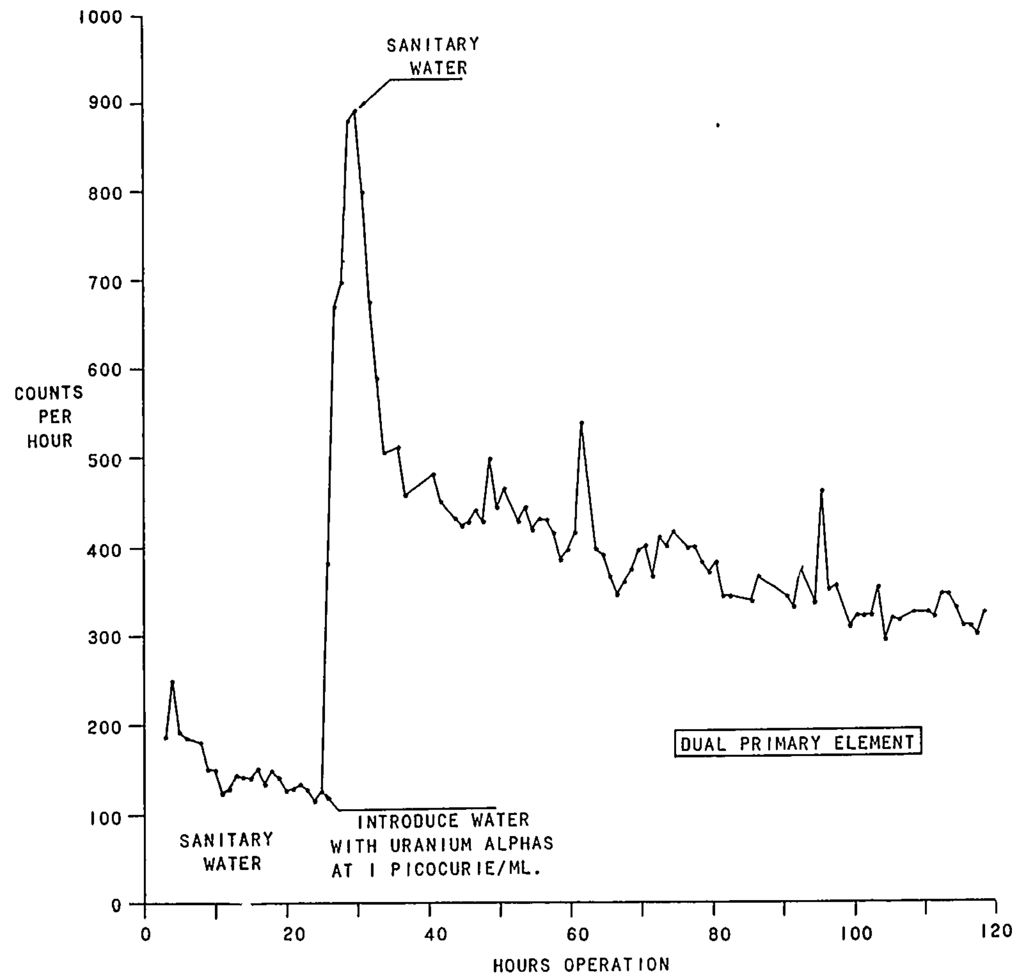
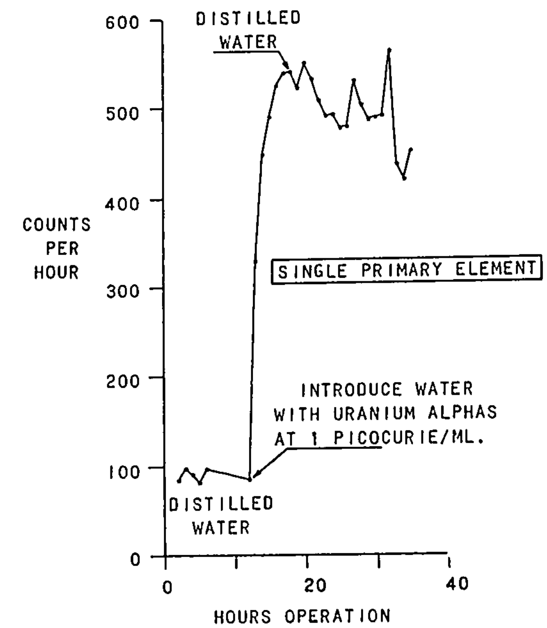


Figure 6

DETECTOR SYSTEM EFFICIENCY FOR FOUR SOURCE LOCATIONS



7a



7b

Figure 7

SENSITIVITY TEST RESULTS.
THE FLOW IN BOTH CASES WAS 60 ML./HR.

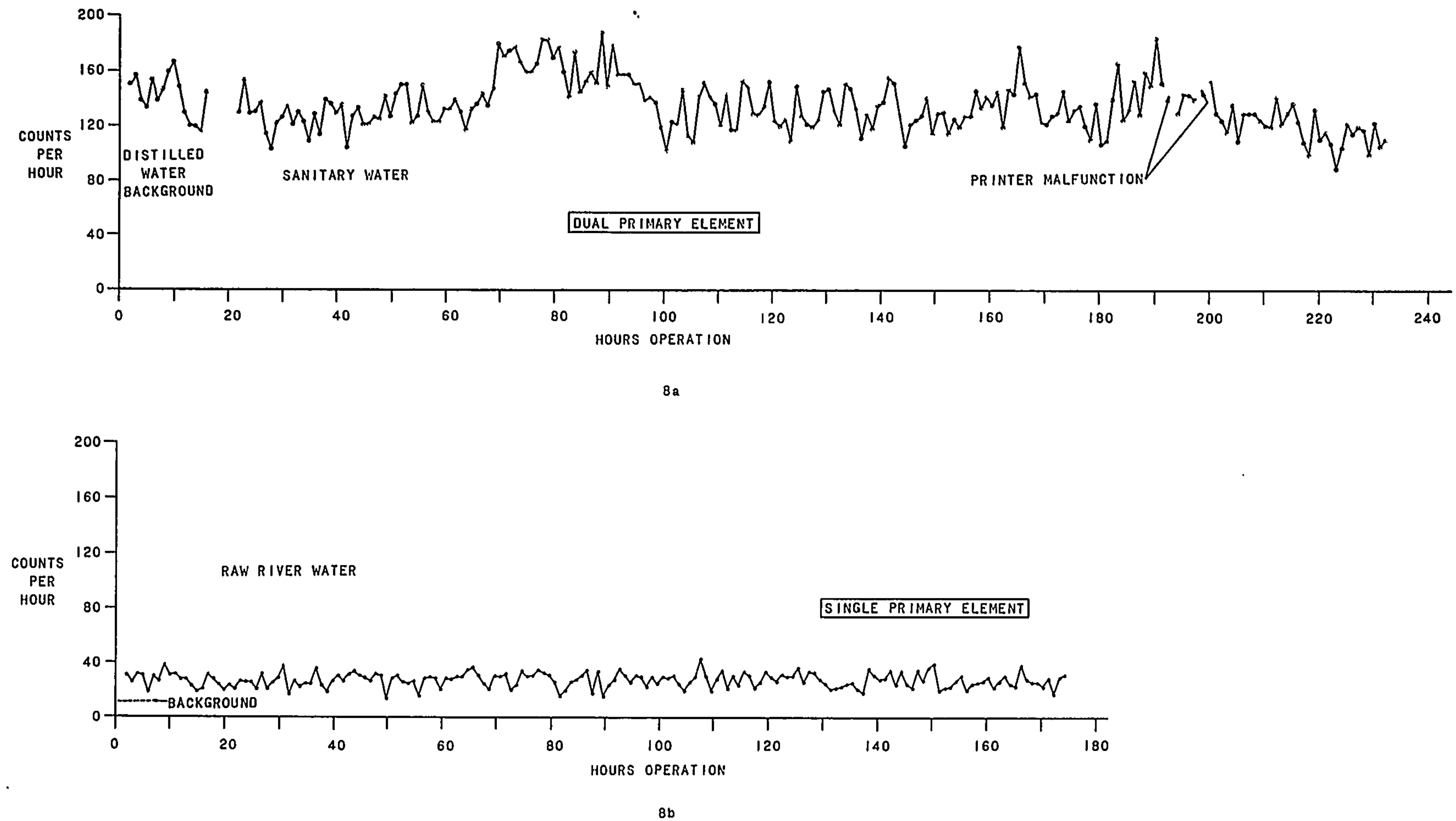


Figure 8

CLINCH RIVER WATER TEST RESULTS.
THE FLOW IN BOTH CASES WAS 60 ML./HR.